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STUDY OF STRESS ANALYSIS OF THE JL-6

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STUDY OF STRESS ANALYSIS OF THE JL-6.

INTRODUCTION.

The airplane known in America as the JL-6 is the T-13 of Prof. Hugo Junker. The airplane is constructed entirely of metal, chiefly duralumin, and contains several unique structural features. The most important features are the multispar wing bracing and the monocoque type of fuselage. Both of these types of construction are extremely difficult to design rationally, as they are very indeterminate statically. Fortunately, the Air Service has been able to obtain through Mr. A. Klemin blue prints of some of the stress analysis used in the design of this airplane. This data has been carefully gone over to learn as much as possible of the methods used by Prof. Junker in making his design.

CHASSIS.

The data on the chassis is meager. Results of tests on individual chassis struts are given and the ultimate strength of the chassis stated, but the connecting links in the analysis are missing. The type of chassis used, however, is not at all difficult to design. It is of interest to note that the resilience of the chassis is translated into height of drop which the chassis can sustain. This drop is 0.5 meter, or about 20 inches.

FUSELAGE.

Apparently a static test was made of a smaller but similar fuselage for the T-10 and the assumptions made that the strength of the T-10 and T-13 fuselages was in proportion to the ratios of the heights and breadths of the two designs. This would probably be the case if the larger fuselage were not more subject to local crinkling failure. The actual failing load of the JL-6 as found in static test at McCook Field was about 80 per cent of that predicted by the designer.

A computation of the strength of a fuselage bulkhead was given but no connection with probable loads is shown. Also a diagram is shown to indicate the strength of the fuselage in case of accident resulting in the airplane landing upside down. No information of value for purposes of stress analysis was drawn from either of them.

EMPENNAGE.

The data on the empennage is insufficient to give a clear idea of the methods used in its design. The designer takes into account the fact that at some angles of attack the loads on the stabilizer and elevator are in different directions. Some stress diagrams were shown, but no information of value was obtained from them.

WINGS.

The most interesting information obtained from the data on hand was in respect to the method of designing the wings. While the available information was insufficient to make it possible to state definitely the methods used in its design, enough was given for one to learn the general outline of the method. One of the chief difficulties in interpreting the computations was the fact that it was not found possible to get an exact check on the figures in those cases where a step was left out. It is believed, however, that the procedure used was, in general, that described below.

The net load on the wing was computed, making an allowance for wing tip loss, and moment and shear curves were drawn for the wing as a whole. This was done for two cases. In Case I the load per square foot was assumed constant over the entire wing except for the wing tip loss. In Case II the load per square foot was assumed constant over a reduced wing. This reduced wing had the same chord at the center as the actual wing but only two-thirds the chord of the actual wing at the tip. As Case I was more severe than Case II the design was made for that condition of loading.

As the spar tubes are very rigidly connected by the web diagonals the whole wing was assumed to act as a unit and the location of the center of pressure neglected. The unit stress in each tube was obtained from the formula $f = My/I$ where y is the distance from the neutral axis to the tube in question, and I the moment of inertia of the tubes about the neutral axis. The tube size was chosen so that I would be large enough to make f a reasonable value in the most stressed tube. Apparently, 50×2 mm. tubes were first chosen and the gauge reduced later to 1.5 mm. To find the stresses in the diagonal members, the vertical projection of the deepest of the trusses was drawn up and the entire load on the wing divided into panel loads on this truss. The stresses in this truss were then computed under the loads shown. Having found what the stresses in this truss would be if it carried the entire load it was desired to compute the proportion of the entire load actually carried by it. This was done from the formula

$$S = \frac{100\, M_b\, e\, g}{I\, P}$$

M_b is the moment on the wing at some section b, I the moment of inertia of the tubes at that section, and e the distance from the neutral axis of the most stressed tube. $M_b\, e/I$ is therefore the intensity of stress in that tube. Section b is taken in this case where the wing is attached to the fuselage. Multiplying $M_b\, e/I$ by g, half the cross sectional area of the tube gives the actual load in one chord of the truss. One-half the area of the tube is used as each

tube is a chord member of two trusses. P is the load in the chord member if the entire load is carried by the one truss. S, therefore, is the per cent of the total load carried by the one truss. In the JL-6 the load carried by the worst stressed truss is computed as 25.6 per cent of the total. The stresses in the members of the deepest truss under the entire load are multiplied by 0.256 to find the actual loads. The loads in the chord members are multiplied by 2.0 as each tube is a member of two trusses, while the loads in the web members are corrected to allow for the difference in slope between the actual member and its vertical projection. The factors of safety are then computed for the members of the deepest truss. The shallower trusses are assumed to be relatively stronger than the deepest one and the stresses were not computed.

The minimum factor of safety, according to the computations, is 4.6 and is at a section about midway between the wing tip and the connection between the wing section and the fuselage section. The actual failure in static test, however, was a tension failure at the joint between wing section and fuselage section, and occurred under a load of 6.5. The wings safely supported a load of 6.0. This shows that the method of design is approximate and not precise, but that it is conservative.

The wing structure obtained is heavier than would have been a wooden structure of the Fokker monoplane type. The Fokker has a slightly heavier wing loading which is in its favor, but a greater effective aspect ratio and a higher strength factor, both of which are in favor of the Junker, yet the Fokker wings weigh only 1.565 pounds per square foot to 1.546 for the JL-6. On the other hand, the Junker construction is much stiffer than the Fokker.

In computing the moment of inertia of the group of tubes little error will be made if the horizontal line through the center of gravity be assumed the neutral axis. In the JL-6 the angle between this line and the true neutral axis is nery small.

STRENGTH OF DURALUMIN.

With the data on the JL-6 was a chart giving the results of compression tests on a series of duralumin tubes. These tubes ranged in size from about 2 inches diameter 0.060 gauge to 0.6 inch diameter 0.020 gauge. The test results are plotted with values of the failing load in kilograms per square millimeter as ordinates and ratios of length to diameters as abscissas. The tubes were tested as pin ended struts. In addition to the test results a mean curve is plotted for use in design. This mean curve is made up of a straight line for short struts and Euler's curve for long ones. Translating the units from the metric to the English system the equations of the mean curve are as follows:

Straight line:

$P/A=57{,}000-1{,}492\ L/d$ (d is the diameter of the tube).

Euler:

$P/A=\frac{\pi^2 E}{8(L/d)^2}$ with $E=10{,}700{,}000$ pounds per square inch.

The above expressions are those used in the test, the actual curves plotted are a little below those values.

The curve plotted from the equation $P/A=47{,}000-400\ L/\rho$ and $P/A=\frac{\pi^2 E}{(L/\rho)^2}$ with $E=9{,}725{,}000$ pounds per square inch, which has been tentatively adopted by the Air Service, agrees very well with the weaker test results obtained by Junker, and represents the average minimum rather than the average strength of the tubing given by Junker's curves.